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APPLICATION
FOR
UNITED STATES
LETTERS PATENT

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FOR: WAVELENGTH DIVISION MULTIPLEX
TRANSMISSION SYSTEM

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Specification

Title of the Invention

Wavelength Division Multiplex Transmission System

Background of the Invention

The present invention relates to a wavelength division multiplex transmission system and, more particularly, to the addition of operating wavelengths in a wavelength division multiplex transmission system for transmitting N light signals having different wavelengths by wavelength division multiplexing.

As shown in Fig. 7, a conventional wavelength division multiplex transmission system of this type used for the addition of operating wavelengths includes n λn CW (Continuos Wave) light generating sections 11-1 to 11-n serving as dummy light generating sections, n λn switching circuit sections 12-1 to 12-n, and a wavelength multiplexing section 14.

The λn CW light generating sections 11-1 to 11-n output CW light beams having the same wavelengths as operating wavelengths. The λn switching circuit sections 12-1 to 12-n receive the CW light beams output from the λn CW light generating sections 11-1 to 11-n and the operating wavelengths output from λn input terminals 15-1 to 15-n, and output the CW light beams, input from the λn CW light generating sections 11-1 to 11-n, to a wavelength multiplexing section 13 without

any change when operating wavelengths λn are not input. Fig. 8 shows this state.

When the wavelength λn is used as an operating wavelength, the λn switching circuit section 12-n outputs the light signal input from the λn input terminal 15-n to the wavelength multiplexing section 14 without any change. Fig. 9 shows this state. The wavelength multiplexing section 14 wavelength-multiplexes the n different light signals from the λn switching circuit sections 12-1 to 12-n and outputs the resultant signal to an output terminal 16.

According to the above conventional method of adding operating wavelengths, however, n λn CW light generating sections 11-1 to 11-n and n λn switching circuit sections 12-1 to 12-n must be prepared. This leads to an increase in apparatus size. In addition, an increase in apparatus size will increase the cost and power consumption.

Summary of the Invention

It is an object of the present invention to provide a wavelength division multiplex transmission system which can add operating wavelengths without changing the total output level at the output terminal of an apparatus in use and the output level per operating wavelength.

In order to achieve the above object, according to the present invention, there is provided a

wavelength division multiplex transmission system comprising N/2 (N is the maximum number of wavelengths to be used) continuous wave light generating means, each for generating continuous wave light having the same wavelength as one of input even- and odd-numbered wavelengths used as operating wavelengths and outputting continuous wave light having a level twice as high as an input level of a light signal having an operating wavelength, N/2 switching means, each for selecting one of an input wavelength and continuous wave light output from the continuous wave light generating means, and wavelength multiplexing means for outputting the other light signal of input light signals having even- and odd-numbered wavelengths and a light signal having different wavelength which is output from the switching means upon wavelength multiplexing.

<u>Brief Description of the Drawings</u>

Fig. 1 is a block diagram showing a wavelength division multiplex transmission system according to an embodiment of the present invention;

Fig. 2 is a block diagram showing a λn switching circuit section in Fig. 1;

Fig. 3 is a flow chart showing the control operation of a control section in Fig. 1;

Fig. 4 is a graph showing a wavelength adding procedure in the absence of an operating wavelength in the system shown in Fig. 1;

Fig. 5 is a graph showing a wavelength adding procedure in the presence of one operating wavelength in the system shown in Fig. 1;

Fig. 6 is a graph showing a wavelength adding procedure in the presence of two operating wavelengths in the system shown in Fig. 1;

Fig. 7 is a block diagram showing a conventional wavelength division multiplex transmission system;

Fig. 8 is a graph showing a wavelength adding procedure in the absence of an operating wavelength in the conventional system in Fig. 7; and

Fig. 9 is a graph showing a wavelength adding procedure in the presence of one operating wavelength in the conventional system in Fig. 7.

Description of the Preferred Embodiment

The present invention will be described in detail below with reference to the accompanying drawings.

Fig. 1 shows a wavelength division multiplex transmission system according to an embodiment of the present invention. Referring to Fig. 1, the wavelength division multiplex transmission system according to this embodiment is comprised of n/2 λi CW light generating sections 1-j (i = 2, 4,..., n, j = 1 to n/2), n/2 λi switching circuit sections 2-j, a control section 3, and a wavelength multiplexing section 4. When, therefore, i = n, the λi CW light generating section 1-i is

represented by a λn CW light generating section 1-(1/n), and the λi switching circuit section 2-j is represented by a λn switching circuit section 2-(1/n) where n is the maximum number of wavelengths used in the wavelength division multiplex transmission system. Note that if n is an odd number, the even integer obtained by increasing (incrementing) the odd number by one is set as n.

Each λi CW light generating section 1-j generates CW light having the same wavelength as an operating wavelength, and also outputs CW light of a level twice as high as the input level of a light signal having an operating wavelength which is input from the corresponding λi input terminal. Each λi switching circuit section 2-j receives the CW light output from the λi CW light generating section 1-j and the operating wavelength input to the λi input terminal, and outputs one of the signals to the wavelength multiplexing section 4. When a wavelength λk and an neighboring wavelength λk-1 are not used as operating wavelengths, the λi switching circuit section 2-j outputs the CW light output from the corresponding λi CW light generating section 1-j to the wavelength multiplexing section 4 without any change in accordance with a switching control signal from the control section 3. In this case, k represents the specific ordinal wavelength number in a wavelength region of the 1st to

nth wavelengths.

When the neighboring wavelength λk-1 is used as an operating wavelength and the wavelength λk is not used as an operating wavelength, the λi switching circuit section 2-j selects the CW light output from the λi CW light generating section 1-j in accordance with a switching control signal from the control section 3. The λi switching circuit section 2-j also adjusts the optical level of the selected CW light to 1/2 in accordance with a CW light output level adjustment control signal 102, and outputs the resultant light to the wavelength multiplexing section 4. When the neighboring wavelength λk-1 is used as an operating wavelength and the wavelength λk is also used as an operating wavelength, the λi switching circuit section 2-j outputs the wavelength λk input from the λk input terminal to the wavelength multiplexing section 4 without any change in accordance with a switching control signal from the control section 3.

The control section 3 outputs a switching control signal and CW light output level adjustment control signal to the λi switching circuit section 2-j depending on the operation state of a wavelength. If the wavelength λk and neighboring wavelength λk-1 are not used as operating wavelengths, the control section 3 outputs a switching control signal 101 to the λi switching circuit section 2-j to output the CW light

input from the λi CW light generating sections 1-j to the wavelength multiplexing section 4. At the same time, the control section 3 outputs the CW light output level adjustment control signal 102 to maintain the optical level of the CW light input from the λi CW light generating section 1-j.

When the neighboring wavelength λk-1 is used as an operating wavelength and the wavelength λk is not used as an operating wavelength, the control section 3 outputs the switching control signal 101 to the λi switching circuit sections 2-j to output the CW light input from the λi CW light generating section 1-j to the wavelength multiplexing section 4. At the same time, the control section 3 outputs the CW light output level adjustment control signal 102 to adjust the optical level of the CW light input from the λi CW light generating section 1-j to 1/2.

When the neighboring wavelength λk-1 is used as an operating wavelength and the wavelength λk is also used as an operating wavelength, the control section 3 outputs the switching control signal 101 to the λi switching circuit section 2-j to output the operating wavelength λk input to the λk input terminal to the wavelength multiplexing section 4. At the same time, the control section 3 outputs the CW light output level adjustment control signal 102 to adjust the optical level of the CW light output from the λi CW

light generating section 1-j to 1/2.

The wavelength multiplexing section 4 outputs light signals which have wavelengths λ1, λ3,..., λn-1 and are input to input terminals 15-1, 15-3,..., 15-(n-1) and light signals which have different wavelengths and are output from the λi switching circuit sections 2-j to the output terminal upon wavelength multiplexing.

Fig. 2 shows the arrangement of the λn switching circuit section 2-(n/2). Referring to Fig. 2, the λn switching circuit section 2-(n/2) is comprised of a level adjusting section 21-(n/2) and a switch section 22-(n/2). Note that each of the switching circuit sections 2-{(n/2)-1} for the λ2 switching circuit sections 2-1 to λ(n-2) has the same arrangement as that of the λn switching circuit section 2-(n/2) shown in Fig. 2.

In the λn switching circuit section 2-(n/2) having this arrangement, the level adjusting section 21-(n/2) adjusts the level of CW light from the λn CW light generating section 1-(n/2) in accordance with the CW light output level adjustment control signal 102 from the control section 3, and outputs the resultant light to the switch section 22-(n/2). The switch section 22-(n/2) selects one of the operating wavelength input to the λn input terminal and the CW light whose level was adjusted by the level adjusting section 21-(n/2) in

accordance with the switching control signal 101 from the control section 3, and outputs the selected one to the wavelength multiplexing section 4.

The control operation of the control section 3 will be described next with reference to Fig. 3. An addition method of keeping the total output level at the output terminal of the apparatus constant and also keeping the output level per operation wavelength constant will be described below by exemplifying the case where wavelengths $\lambda 1$ and $\lambda 2$ are added in the absence of an operating wavelength.

First of all, the control section 3 checks the operation states of all wavelengths $\lambda 1$ to λn (step S1). If it is determined in step S1 that none of the wavelengths $\lambda 1$ to λn are used as operating wavelengths, the control section 3 outputs the logic-"1" switching control signal 101 to all the λi switching circuit sections 2-j to output CW light beams from the λi CW light generating sections 1-j to the wavelength multiplexing section 4. At the same time, the control section 3 outputs the logic-"0" CW light output level adjustment control signal 102 to all the λi switching circuit sections 2-j to keep the optical levels of the CW light beams output from the λi CW light generating sections 1-j unchanged (step S2).

In response to this signal, all the λi switching circuit sections 2-j output the CW light beams

output from the λi CW light generating sections 1-j to the wavelength multiplexing section 4. Fig. 4 shows this state.

If it is determined in step S1 that the wavelength $\lambda 1$ is used as an operating wavelength and the wavelength $\lambda 2$ is not used as an operating wavelength, the control section 3 outputs the logic-"1" switching control signal 101 to the $\lambda 2$ switching circuit section 2-1 to output the CW light beam from the $\lambda 2$ CW light generating section 1-1 to the wavelength multiplexing section 4. At the same time, the control section 3 outputs the logic-"1" CW light output level adjustment control signal 102 to the $\lambda 2$ switching circuit section 2-1 to lower the optical level of the CW light beam output from the $\lambda 2$ CW light generating section 1-1 to 1/2 (step S3).

The control section 3 outputs the same logic-"1" switching control signal 101 and logic-"1" CW light output level adjustment control signal 102 as those described above to other wavelength switching circuit sections 2-2,..., 2-(n/2). With this operation, the optical level of the CW light beam output from the $\lambda 2$ CW light generating section 1-1 is adjusted to 1/2 by the $\lambda 2$ switching circuit section 2-1. The resultant light beam is output to the wavelength multiplexing section 4. Fig. 5 shows this state.

If it is determined in step S1 that both the

wavelengths $\lambda 1$ and $\lambda 2$ are used as operating wavelengths, the control section 3 outputs the logic-"0" switching control signal 101 to the $\lambda 2$ switching circuit section 2-1 to output the operating wavelength $\lambda 2$ input to the $\lambda 2$ input terminal 15-2 to the wavelength multiplexing section 4. At the same time, the control section 3 outputs the logic-"1" CW light output level adjustment control signal 102 to the $\lambda 2$ switching circuit section 2-1 to lower the optical level of the CW light beam output from the $\lambda 2$ CW light generating section 1-1 to 1/2 (step S4).

The control section 3 outputs the same logic-"0" switching control signal 101 and logic-"1" CW light output level adjustment control signal 102 as those described above to the other wavelength switching circuit sections 2-2,..., 2-(n/2). With this operation, the operating wavelength input to the $\lambda 2$ input terminal is output from the $\lambda 2$ switching circuit section 2-1 to the wavelength multiplexing section 4 without any change. Fig. 6 shows this state.

As described above, when wavelengths are to be added, the wavelength $\lambda n-1$ is used first, and then the wavelength λn is used.

By preparing the λi CW light generating sections 1-j and λi switching circuit sections 2-j for only even-numbered (or odd-numbered) wavelengths in this manner, wavelengths can be added at low cost without

affecting transmission path characteristics. In addition, the mount space of a transmission apparatus can be reduced, and hence the power consumption can be reduced.

In the above embodiment, the maximum number N of wavelengths is an even number. If, however, the maximum number N of wavelengths is an odd number, CW light generating sections half the even number obtained by increasing (incrementing) the odd number by one may be prepared to make the number of wavelengths even. In this case, the switching circuit and control section perform the following operation for the wavelength λn (odd-numbered) and wavelength $\lambda n+1$ (even-numbered wavelength upon increment).

If the wavelength λn (odd-numbered wavelength) and wavelength $\lambda n+1$ (even-numbered wavelength upon increment) are not used as operating wavelengths, the switching circuit outputs the CW light output from the $\lambda n+1$ CW light generating section to the wavelength multiplexing section without any change in accordance with a switching control signal from the control section.

If the wavelength λn (odd-numbered wavelength) is used as an operating wavelength and the wavelength $\lambda n+1$ (even-numbered wavelength upon increment) is not used as an operating wavelength, the switching circuit selects the CW light input from the λ

n+1 CW light generating section in accordance with a switching control signal from the control section and also adjusts the optical level of the CW light to 1/2 in accordance with a CW light output level adjustment control signal from the control section. The switching circuit then outputs the resultant CW light to the wavelength multiplexing section.

If the wavelength λn (odd-numbered wavelength) and wavelength $\lambda n+1$ (even-numbered wavelength upon increment) are not used as operating wavelengths, the control section outputs a switching control signal to the $\lambda n+1$ switching circuit section to output the CW light input from the $\lambda n+1$ CW light generating section to the wavelength multiplexing section, and also outputs a CW light output level adjustment control signal to keep the optical level of the CW light input from the $\lambda n+1$ CW light generating section unchanged.

If the wavelength λn (odd-numbered wavelength) is used as an operating wavelength and the wavelength $\lambda n+1$ (even-numbered wavelength upon increment) is not used as an operating wavelength, the control section outputs a switching control signal to the $\lambda n+1$ switching circuit section to output the CW light input from the $\lambda n+1$ CW light generating section to the wavelength multiplexing section, and also outputs a CW light output level adjustment control signal to

adjust the optical level of the CW light input from the $\lambda n+1$ CW light generating section to 1/2.

As described above, according to the present invention, operating wavelengths can be added without changing the total output level at the output terminal of an apparatus in use and the output level per operating wavelength. According to the wavelength adding method for the wavelength division multiplex transmission system according to the present invention, in the wavelength division multiplex transmission system for transmitting N light signals having different wavelengths by wavelength division multiplexing, CW light generating sections and switching circuit sections are prepared for only even-numbered (odd-numbered) wavelengths.

With this arrangement, wavelengths can be added at low cost without affecting transmission path characteristics. In addition, the mount space of a transmission apparatus can be reduced, and the power consumption can be reduced. Furthermore, operating wavelengths can be added without changing the total output level at the output terminal of an apparatus in use and the output level per operating wavelength.